

History & Perspectives

Setting the Standard: NIST/NBS at 100 Years

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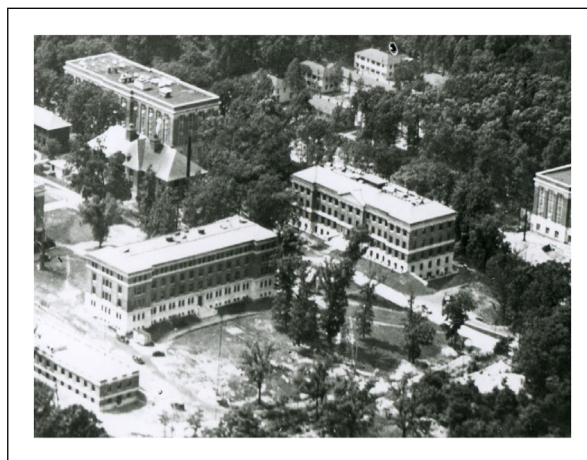
Former Director, National Bureau of Standards (NBS), 1969-1972



SLIDE 1

I joined the NBS staff just 50 years ago. 1951 was an exciting time at NBS, as 2001 is at NIST. NBS was emerging from 20 years of depression and war. Ed Condon was director; he recruited quite a number of young scientists after the war Ernie Ambler, Steve Smith, Karl Kessler, Charlie Herzfeld, Herb Broida, Pete Bender, John Hall, Larry Kushner, Jack Hoffman, and lots of others. It was good time to be a scientist. People at cocktail parties acted impressed when you were introduced as a physicist. We young scientists were cocky and irreverent; I guess some of us still are. We looked to a future both threatened by nuclear weapons and bright with the promise of expanding national investments in science and technology. But we had no doubts about what we could accomplish in science and what science could do for the world.

Still, it is hard to realize how different things were in 1951. When you went out Connecticut Avenue to Van Ness Street you felt like you were going out into the countryside. If you were attending the spring meeting of the American Physical Society, all of you met in room 250 of the NBS East Building. [Slide 2] The National Science Foundation was only one year old. ONR was creating a new relationship between science and the military, which would set a precedent for other agencies later.




SLIDE 2

Compared to today, science was in an incredibly primitive state at that time. Biology was largely descriptive. Chemistry was heavily empirical and rested primarily on valence theory and symmetry properties. The Quantum Theory was still young, and only two body mechanics could be solved exactly. Engineers prided themselves on being able to do things science could not explain, based on their experience and tacit knowledge. In those days science required a National Bureau of Standards to press forward with new instruments, accurate measures of the property of matter and materials, and all of the methods of precise and accurate measurement. It was no accident that NBS focused on its reputation in basic science, and men like Edward U. Condon, one of the leading theoretical physicists of his day, were appointed Director.¹ [Slide 3]

1951 was also the year Ed Condon left the Bureau's directorship for the Corning Glass Works. Ed, who was born in Alamogordo, NM, had tried to educate the congress about nuclear weapons and fought for civilian control. In return Congressman J. Parnell Thomas, who wrote in a House Un-American Activities Committee report, attacked him, "It appears that Dr. Condon is one of the weakest links in our atomic security." Ed stayed on as Director long enough to see Congressman Thomas thrown in federal prison. [Slide 4]

¹ Edward Uhler Condon was director of NBS from 1945 to 1951.

Edward Uhler Condon,
NBS director 1945 - 1951



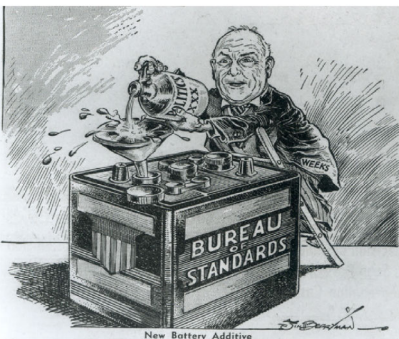
Ed Condon, a great theoretical physicist and a fine director, hired many of the NBS "young Turks" but was a bit too direct for some Congressmen.

SLIDE 3



Jesse Ritchie,
maker of
battery
additive
ADX-2


SLIDE 5



Sinclair Weeks,
new Secretary
of Commerce,
cartooned for
bringing politics
into the NBS.
He proved
worthy of his
responsibilities
after a rocky
start.

"New Battery Additive"

SLIDE 4



All's well that
ends well.

Astin and
Weeks
became
good friends.

SLIDE 6

But quite apart from the political abuse he received, he left just in time to avoid the gravest challenge to the Bureau's scientific integrity the firing of his successor, NBS director Alan Astin over battery additive ADX-2.²

I am sure you all know the story of this challenge to the Bureau's electrochemistry work by an ambitious entrepreneur named Jesse Ritchie. [Slide 5] I discussed that story on Monday; let me here only reiterate that had the Bureau not stuck to its guns, had the scientific community especially the Statutory Visiting Committee and the National Academy of Sciences not come to its aid, and had Secretary of Commerce Sinclair Weeks not been a man of extraordinary integrity himself, willing to

² Technically, Weeks did not "fire" Astin, who served at the pleasure of the President; he asked for his written resignation. Presumably he did not send the resignation to the White House, since if it had been accepted President Nixon would have had to reappoint Astin and the Senate would have had to reconfirm him.

admit and correct a mistake, the fine NIST laboratory we see today, here and Boulder, would not exist.

[Slide 6]

In the 1950s, the Bureau's responsibility for providing the underpinnings for progress in science loomed large in its vision, in no small part due to Marvin Kelly's advice to Secretary Weeks following the ADX-2 debacle. For science to mature as a source of new technology and of understanding how to use that technology, its quantitative base had to be secure. This is a huge task. Very few scientists in academic settings make absolute measurements. Everyone assumes that their work can be related to the real world by reference to measurements traceable to NIST. [Slide 7] I am my contention that the incredible progress of science and of engineering and medicine in the last 50 years, made possible by the work of NBS/NIST and its sister laboratories abroad, has transformed the nature of

science and engineering and has altered profoundly the environment within which NIST must set its priorities.

Today the U.S. innovation rate far exceeds anything society has experienced in the past. This is made possible by the richness of the stock of scientific knowledge and the power of the tools of technology to dip into that stock and create new materials, new processes, new ways of solving problems to fit the needs of the moment. [Slide 8] *The limitations on solving problems are no longer mainly technical; they are socio-economic and even cultural, institutional, and political.* This trend places even more serious demands on institutions like NIST and puts the world of standards making in a new light. It is my contention that we are



Science & the Physical World

- Connecting science to Mass, Length, Time – the world in atomic units
- Statistical and systematic errors – when is an experiment finished?
- NBS/NIST: technical conscience for the US federal government.

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Solving society's problems

- The limitations are no longer primarily technical, even though risks are high
- They are socio-economic and even cultural, institutional and political.

SLIDE 8

just beginning to fully understand the processes by which science creates economic opportunities and these opportunities are realized in a socially constructive manner.

Today's discussion has been about standards. For most people this brings up thoughts of finding a metric wrench with which to tighten a metric screw, or setting the rules for inspecting beef. For most people standards is a MEGO subject if there ever was one.³ But of course this audience understands that engineering standards are the language of commerce, that the whole industrial system would collapse if every time a firm sent out a purchase order for screws it had to spend 6 months studying the design and metallurgy of screws and then write a 100 page engineering test specification for the parts it wanted to put out for bid.

[Slide 9] *Standards are ultimately about the ability to specify, accurately and quantitatively, the function, performance, and reliability of a physical object or a technical system.* This capability is what enables and sustains the progress of science, of technology, of invention and of innovation, and ultimately of citizen satisfaction. This ability to characterize an object or a system in quantitative terms—with known accuracy—in traceable units of measurement—is not only essential to buying nuts and bolts. It is essential to traversing the so-called Valley of Death to reach the goal of a new product innovation. [Slide 10] NIST is engaged in a way unique to our government with every step in that national system of innovation.

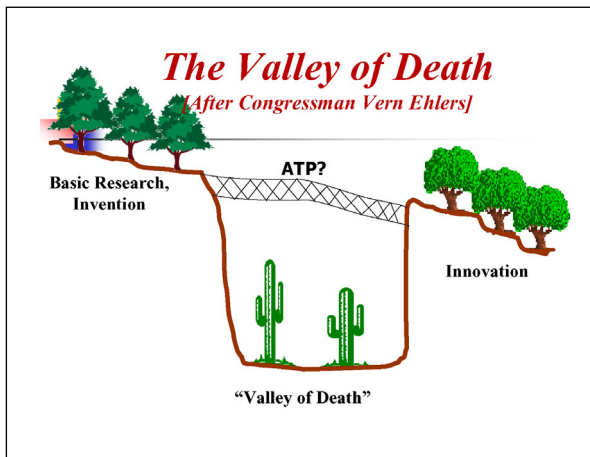


Standards

- Are ultimately about the ability to specify quantitatively and accurately the function, performance, and reliability of a physical or technical system.
- This is also what an innovator must do when transferring a new invention into an innovation. He must also specify the costs and the most likely market.

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³ MEGO = "My Eyes Glaze Over"



SLIDE 10

I want to persuade you, in the few minutes that remain to us in this great celebration, of four things:

1) Market forces alone will not sustain the fruitful and efficient transformation of high tech inventions to innovations; there is a critical role for government in basic technological research required, performed collaboratively with firms and with universities, to facilitate that transformation. The NIST Advanced Technology Program, ATP, is the only serious effort in the U.S. Government to understand this need and find the right government role in addressing it. It should be improved and expanded, not killed as its conservative critics call for.

2) For society to make wise technological choices through democratic processes, the legitimacy of the technical experts and the integrity of their institutions must be established and sustained. NIST is not just another agency, another government laboratory. It must be, and is, a uniquely trusted partner in addressing technical issues vital to the public interest.

3) Once that legitimacy is established institutions like NIST must create the institutional environment in which the connections between technical activities and the interests of citizens and government officials can be based on trust. NIST does not throw its technical knowledge over the transom, so to speak; it must help create the receptive processes and institutions that can use that knowledge in the public interest. This is what all the standards committee participation, all the ATP and MEP projects do.

4) Science not only creates technological opportunities; it informs us on how to make the right technological choices. This requires a consciousness of social issues and humane values that must inform the collective judgments of society, made through democratic processes. NIST cannot carry out this very important and challenging mission without a broadly based and powerful capacity in basic scientific and technological research and research on the processes of the innovation transformation.

Let address these four issues in turn.

The US Government must implement the responsibility it undertook in the 1988 Trade and Competitiveness Act to ensure that the system of discovery, invention, and innovation in our society is healthy. This requires an extraordinarily sophisticated matching of public investments in science and research to private investments in entrepreneurship and economic growth. [Slide 11] The conventional model is of two separate systems one the science research system, with its laboratories, graduate schools, and its public support—the other the system of businesses, with their own management schools and systems of capital aggregation and finance. These two systems are very poorly connected. Yet the flow of value from \$90 billion in public funded research to a trillion dollar manufacturing economy depends on that linkage. Congressman Vern Ehlers' Valley of Death diagram illustrates the nature of this gap and emphasizes the risks entailed in its transit. But a desert is a poor metaphor for this gap, except in emphasizing those risks. I prefer a metaphor of an ocean alive with competing new forms of life.



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There are three serious barriers⁴ to entering that ocean on one side and emerging with a viable new form of life—a new enterprise based on new science—on the other side:

- Inventors, business managers, and venture investors do not share common motivations, language, or even trust.
- The research to reduce an innovative idea to practice and create product and process specifications that match a market is not the kind of science familiar to universities or the more incremental engineering practiced in established firms.
- That research is not often financed by either the S&T establishment or by the business investment establishment; it depends on a chaotic arrangement of angel investors, seed capital investors, bootstrapped investments by entrepreneurs and a very few experimental government programs, of which NIST's ATP is by far the most seriously thought out approach.

I regard the ATP program as a critical learning opportunity for government, in exploring the risks and rewards of the transition from invention to innovation and the government's role in reducing those risks while expanding the social returns to the entire economy. My research suggests to me that even at the current budget, well below that sought by President Clinton and far below the public funds spent on SBIR, ATP can make a big difference. Its effectiveness might be maximized if ATP can find excellent projects in states other than California, Massachusetts, Texas, and New York, and out of the more trendy fields such as biotech and information technology.⁵ On that basis I believe the research Philip Auerswald and I are doing will find that ATP investments even at the current level would not be

not small compared to private, early stage sources of research funding for high tech innovations.⁶

But quite apart from the stimulation ATP makes to new technologies and new values for society, it is also teaching a lot about the interplay of market and technology and the central role that product specifications play in the invention to innovation transition. This coupling of markets and science, through product specs, demands the kind of creative research we expect from our universities and the kind of disciplined choices we know we must make in our economy. This is where all our NBS and NIST experience in the characterization of materials and the making of accurate absolute measurements has taken us—right to the heart of the innovation process. Thus ATP should not be seen as something foreign to the NBS/NIST tradition, but something quite central to it. We mustn't lose it just when we begin to understand its true importance.

My next point is the importance of the integrity and legitimacy of the technical work that both sustains commerce and informs public decisions about the choices and uses of technology. As I told the Congress in its oversight hearings in 1972, the scientific integrity of the National Bureau of Standards is its most valuable technical asset. The committee agreed; its own independent investigation of the NBS concluded that the Bureau must be extraordinarily trustworthy and circumspect, since the investigator could not find any mention of the agency in the Congressional Record, except as related to the annual appropriation cycle.

The Bureau's integrity has, indeed, been tested and found solid. The ADX-2 challenge was only the most serious the Bureau's work had to face in its first 100 years. NBS/NIST has been the scientific adjudicator of a thousand disputes; it has very rarely been found wanting.

Why is does the laboratory have this reputation for integrity? Not just because its integrity has been tested and found strong. I believe it is because NBS/NIST has developed a culture that is committed to absolute measurement and respects the importance of quantifying systematic as well as statistical errors. This culture attracts scientists who want to do science that is too hard to do in a university. That is why I came from Harvard

⁴ See L. M. Branscomb and Philip Auerswald, *Taking Technical Risks: How Innovators, Executives and Investors Manage High-Tech Risks* (Cambridge MA: MIT press) February 2001. This book is based, in part, on research funded by the NIST ATP program in which the MIT Entrepreneurship Program and experts in Entrepreneurship at the Harvard Business School participated. See L. M. Branscomb, Kenneth Morse and Michael Roberts, *Managing Technical Risks: Understanding Private Sector Decision Making in Early-Stage, Technology-Based Projects*. Advanced Technology Program, NIST, U.S. Dept. of Commerce, NIST GCR 00-787, April 2000.

⁵ In 1999 76 % of all new venture capital funding went to biotech, IT and retail, and 67 percent went to ventures in California, Massachusetts, Texas, and New York. There is reason to believe that early stage seed funding was probably even more highly concentrated. ATP grants (throughout its history) averaged 39.6 % to these four states.

⁶ Since angel and seed investors do not have to reveal their activities publicly, and the firms they invest in are almost all private, clear data are not available. But in 1998 one estimate of new seed venture capital investments was about \$1.5 billion, of which only a small part was used for high tech R&D in states other than CA, MA, NY, and TX. Angel investments and bootstrapping by innovators with help from "family, friends, and fools" is estimated at \$3–30 billion; again only a small part is high tech, and only a part of that is for R&D, and only a part is in states other than the leading four. Compare to ATP appropriations in 1998 of \$ 192.5 million, down from a high of \$340.5 million in 1995.

in 1951. NBS/NIST scientists understand the importance of being trusted as the disinterested expert in thousands of voluntary engineering standards committees, and adjudicating technical disputes for other agencies of the government. This culture must be sustained. It is rooted in the very best, often the most difficult, science. And of course, the leaders and the scientists of NBS/NIST do not play politics; we do not believe “the play of the marketplace” has any place in our lab notebooks.⁷

[Slide 12] Third, even though I have said NIST’s legitimacy and integrity depend on freedom from political manipulation, NIST must demonstrate its political sophistication (a small “p,” please) by creating the relationships of trust that allow it to be effective. I gave the example of the 1500 NBS scientists who served on industrial standards committees when I was director. Let me give you another example of how NBS/NIST create human institutions to further the value to the public of its technical services.

The Constitution (Article I, Section 8, Clause 5) gives the Congress the power to “fix the standards of weights and measures” for the nation. NBS might have asked to use that authority to control the weights and measures of the states. But it chose not to. Instead it serves as the secretariat of a National Conference of States on

Weights and Measures, through which state officials voluntarily develop and ask their legislatures to adopt a common set of standards for weights and measures in commerce.

I am impressed by this model. During my directorship we began a similar process hoping to induce all 50 states to adopt common, performance-based building codes and standards, effectively consolidating some 13,000 code jurisdictions without depriving the states of their ultimate authority. The going has been slow, but there are many advantages to this consensual model. Today I wonder if a similar institutional invention might serve to give the nation harmonious but voluntary performance objectives and core curriculum content for public schools.

[Slide 13] Fourth and finally, I must reiterate that all of the value that NIST creates for our society depends critically and absolutely on the quality of its research. The special scientific culture at NIST is unique and irreplaceable. That research tradition should be expanded into understanding the socioeconomic processes that connect NIST activities to beneficial societal outcomes. The most critical events in the economy—the translation of science into innovations engage people with very different outlooks and expectations. The New Economic Growth theory and the new field of behavioral economics must help institutions like NIST to maximize their value to society. The NIST ATP economics research program, of which I am a beneficiary, has sponsored some of the most rigorous evaluation and policy research on the Invention to Innovation transition. It should be sustained and if possible expanded.



Connecting science to people

- NBS/NIST mission: The technology base for science; the science base for technology and innovation
- Science → Technology → People
 - NBS/NIST creates the institutions and processes for delivering value to public
 - Collaboration with state governments is traditional at NBS/NIST

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⁷ The Senate Small Business Committee, in finding NBS at fault for concluding from a chemical analysis that ADX-2 consisted of Epsom and Glauber’s salts that it was not useful to extend the life of automobile batteries, that NBS scientists had “failed to take into account the play of the market place.” The implication is that NBS scientists should have given significant weight to anecdotes by motor pool operators who had tried the additive and believed it was helpful as they gave to the science of electrochemistry.



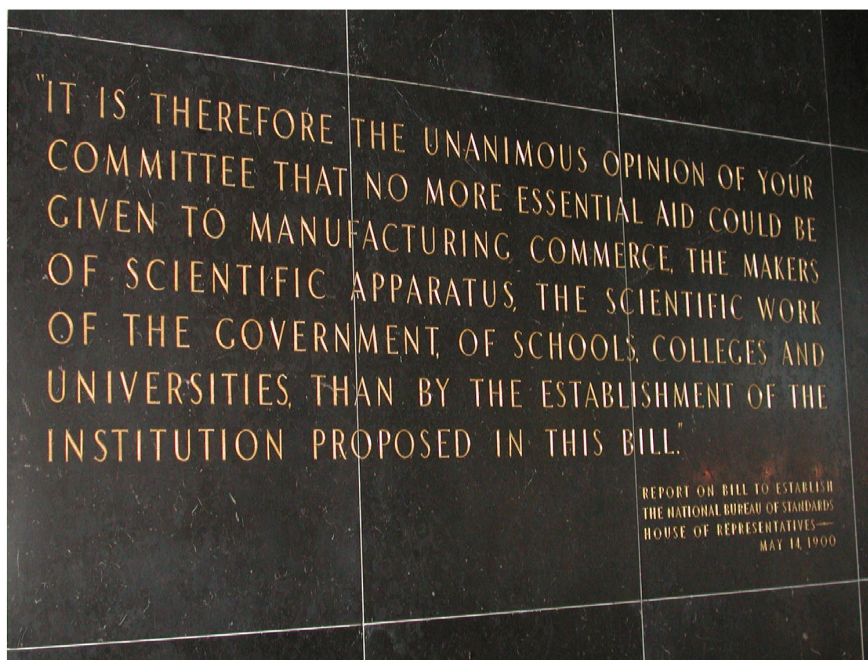
NBS/NIST and Basic Science

- Tradition in science
 - Samuel Wesley Stratton, John Wheeler, E.U. Condon, Ugo Fano, William Phillips...
- A new State of Matter
 - Bose-Einstein Condensates: Cornell & Wieman, JILA – Joint Institute for Laboratory Astrophysics
- Laser cooling and trapping of atoms
 - William D. Phillips’ 1997 Nobel Prize in Physics

SLIDE 13

My final conclusion: this fine institution has served the nation with remarkable fidelity for almost half the life of the nation. It is the cornerstone of the Nation's science, and source of much of its industrial productivity, and now a major factor in finding new ways to foster the radical, science based innovations that Schumpeter understood but only our generation has seen to flower. [Slide 14] NIST's mission is not, alone, to serve the

needs of industry in support of a strong economy; NIST's role is to support the scientific and technical enterprise of the nation in ways that expand its creativity, productivity, and utility to many dimensions of our national life. No other institution covers the full spectrum of service that NIST does and as the Congress so clearly anticipated in its statute of 1900 that led to the founding of NBS in 1901.



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